TAMPERING DETECTION
With New Metering ICs

To control revenue losses, utilities need to detect and continue billing accurately when tampering has occurred. Thankfully, energy metering chips are available that help to implement multiple layers of tamper detection.

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With more electricity connections being metered worldwide, and the cost of electricity rising, the likelihood that an electricity meter will be tampered with has increased.

The newest generation of single-phase metering systems-on-chip (SoCs) is suitable for detection of tampering. In a standalone meter, without long-distance communications, a tampering event can be stored in the memory to be reported during the meter’s monthly polling. The value of tamper detection increases tremendously if the meter is part of an automatic metering management network, where the event can be reported quickly and appropriate action can be taken to investigate and correct the condition.

In smart meters, one common way to detect tampering is to install a case-open switch. The ability to monitor this switch when line power is off is critical as this is when tampering is most likely, due to the reduced threat of injury. Continuously monitoring these switches when the line is ‘off’ requires a very low power consumption mode that can wake up when the case-open switch is activated and record the state of the meter.

In some countries, it is a common practice to use two current sensors in a single-phase design to detect tampering. One current sensor is used to detect phase current and the other to monitor return current, to ensure that they do not differ by more than a specified amount. This allows the meter to record the proper energy under earth fault and partial earth fault tampering conditions.

MISSING NEUTRAL TAMPERING AND ITS DETECTION

A more sinister method of tampering is shown in Fig. 1. The missing neutral tampering condition occurs when the neutral is disconnected from the power meter. Without a voltage reference, the meter’s board ground floats to the line voltage and the voltage sampling input is invalid.

As Fig. 2 shows, when the neutral line is cut at the two points marked ‘1,’ the electric potential at points ‘2’ and ‘3’ is identical. Because there is no neutral reference in the meter, no output can be generated from a normal capacitor- or transformer-based power supply, and the meter will go into its power-down condition. But, if a load is applied, there will be a valid input signal on the current channel and power will be consumed.

How can the meter calculate power when there is no voltage signal input?

First, let’s examine theory. The definition of power is $P=V\times I$, but under the missing neutral condition the voltage input is zero and therefore $P=0$. But, if during this condition we assume that voltage is fixed at a known amplitude and phase, we can substitute a constant for the voltage and the formula becomes $P=k\times I$. 
If we calibrate $k \times I$ to produce the same power output as $V \times I$, when the voltage is at its nominal value, we can estimate the billing when the missing neutral arises. We can simply implement this by setting the power output to be proportional to the $I_{\text{RMS}}$ measurement and adjusting the gain of $I_{\text{RMS}}$ such that $k \times I = V \times I$. Our measurement has changed from watt-hours to amp-hours, which has been scaled to match the ideal voltage condition.

Because we are substituting a constant for the voltage input, we are unable to respond to any change in the power factor (PF) or the amplitude of the voltage channel input. Therefore errors will occur if the PF varies from the calibration point of PF=1 and if the voltage varies from the nominal amplitude.

While these errors are normally unacceptable, this method is more accurate than the result of $P=0$, which would otherwise be measured in a meter without a missing neutral billing mode.

The next problem to consider is that with only one potential entering the meter, all standard ways of developing a DC power supply will not work. Therefore you need to develop
the 3.3V supply only from the current traveling through the meter.

As shown in Fig. 3, use a power current transformer (CT) to output current on its secondary side, which can be used to develop the required power supply voltage.

How to design the missing neutral power supply? With a current transformer having a turns ratio of 200:1 and 2A passing through the primary side, you will have 10mA in the secondary side. You can use the 10mA current to power the meter by placing a full bridge rectifier and a low-quinetsent current regulator like the ADP3330 after the CT.

One issue is if the primary side current continues to increase, the secondary current will follow. If the secondary current becomes too large, it can exceed the rated current of the components. Therefore we must limit secondary-side currents by causing the CT to saturate.

The saturation of the CT is determined by the choice of core material and the number of windings on its two sides. An inexpensive CrGO core works well in this application. One limitation of this type of power supply is that if load current (Ip) is too small, there will not be enough current available on the secondary side for the meter’s power needs.

Selection of the metrology IC. Now let’s consider the selection of the main metrology IC. A basic requirement is that the energy measurement is very accurate and stable over time, temperature and input dynamic range. The second criteria for selection is long-term reliability as the meters are likely to be installed for ten years or more.

While initial accuracy measurements are easy to obtain, determining the long-term accuracy and reliability is significantly more difficult, making the choice of energy measurement vendor harder. This makes the vendor’s reputation in the market important, but there are also long-term reliability tests like high-temperature operating life that can be performed on the IC to test reliability and change in accuracy over time.

As time-to-market pressures are increasing, having a metering SoC that contains the full feature set is also important.

The ADE71xx family of energy metering SoCs contains a highly accurate and stable energy measurement engine. In addition to the dedicated energy measurement circuitry with built-in tamper detection, these SoCs integrate an 8052 microcontroller with flash memory, LCD driver, real-time clock (RTC) and intelligent battery management.

The power management circuitry monitors the main supply voltage and the battery and automatically chooses between normal operation mode and an ultra-low-power 1.5mA battery mode. This enables easy monitoring of the case-open switch and meets specifications in some countries that the display must remain active for several hours after power is lost.

An integrated two-current-channel sampling ADC, with automatic channel selection based on their amplitude, enables an easy way to implement tamper detection for the earth fault condition.

Most smart meters have an LCD to show energy consumption, billing cycle, time, date, RMS voltage and current values. A 104-segment LCD driver can control the display contrast.

As electricity meters are typically placed outdoors, the temperature of the device may vary widely from over 60°C to well below 0°C, which can make the LCD difficult to read. A temperature sensor is used to measure the temperature of the device and a digital-to-analogue converter (DAC) that can vary the voltage amplitude of LCD signals. The integrated hardware RTC has base frequency and temperature compensation, which allows a 2ppm accuracy after calibration.

An integrated two-current-channel sampling ADC, with automatic channel selection based on their amplitude, enables an easy way to implement tamper detection for the earth fault condition.

For the missing neutral tamper detection, the SAG detection interrupt can be used to detect if the neutral has been removed. The ADE71xx can then be internally configured to record the energy based only on the I_{rms} measurement. The IRMS_GAIN can be adjusted to provide the proper ‘k’ value.

To sum up

To control revenue losses, utilities worldwide need to detect and continue billing accurately when tampering has occurred. Energy metering SOCs are available that provide an excellent solution to implement multiple layers of tamper detection, including using their low-power mode to monitor the case-open switch when the line power is off, using the two-current-channel ADC monitor for earth fault tampering and using the SAG detection and I_{rms} to easily implement the missing neutral tamper detection.

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